FROM SHADOWS TO SPOTLIGHT: THE RISE OF ENVIRONMENTAL ACCOUNTABILITY IN EXTRACTIVE INDUSTRIES

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ABSTRACT

This study provides a bibliometric analysis of sustainability disclosure within the extractive industries, with a specific focus on the mining sector. Given the increasing global emphasis on environmental accountability, this research identifies key themes, influential publications, and evolving trends in sustainability reporting. Using bibliometric data from 2006 to 2021, the study analyzes patterns across several major journals, countries, and authors to highlight the development of sustainability disclosure practices. A co-occurrence network of keywords is constructed, revealing four main research clusters: environmental disclosure in China's mining sector, the economic impacts of mining, content analysis linked to legitimacy theory in Canada, and corporate social responsibility (CSR). The thematic map further categorizes these themes by centrality and density, identifying motor themes with high centrality, emerging themes, and isolated but well-developed themes. Additionally, a thematic evolution analysis outlines the progression of environmental disclosure research in four phases, showing how focus areas have shifted from fundamental environmental concerns to more integrated sustainability reporting. The findings underscore the need for more comprehensive, cross-country studies and refined frameworks to better capture the nuances of sustainability practices in extractive industries. This research provides a valuable foundation for future studies, enabling a deeper understanding of sustainability disclosure and its role in promoting environmental responsibility in high-impact sectors.

Keywords: Sustainability disclosure, Extractive Industries, Mining Sector, Environmental Accountability, Corporate Social Responsibility (CSR), Bibliometric Analysis

https://doi.org/10.56249/ijbr.03.01.63
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I. INTRODUCTION

In recent years, sustainability has emerged as a central focus for industries worldwide, especially for sectors with significant environmental and social impacts, such as the extractive industries (Ali et al., 2024). These industries, encompassing mining, oil, and gas, operate in complex ecosystems, often facing scrutiny from regulatory bodies, communities, and environmental organizations due to their intensive use of natural resources and the potential for environmental degradation (Arslan & Bashir, 2021). As the call for corporate accountability and transparency grows, sustainability disclosure has become a crucial tool for extractive companies to communicate their environmental, social, and governance (ESG) initiatives to stakeholders(Arslan, Chengang, et al., 2022).

Sustainability disclosure refers to the practice of reporting non-financial information related to a company's environmental impact, social responsibility, and governance practices(Khan et al., 2022). Such disclosure allows stakeholders to assess a company's commitment to sustainable practices and helps mitigate information asymmetry between firms and their investors, customers, and the broader public(Gerged et al., 2023). For the extractive sector, the relevance of sustainability disclosure is amplified due to its high visibility and potential for socio-environmental impact. Despite the increasing adoption of sustainability reporting, there remains a need to systematically review the literature to understand the influential aspects and conceptual structure underpinning sustainability disclosure in extractive industries(Li et al., 2023). A bibliometric analysis, therefore, provides a valuable methodological approach to uncover the trends, patterns, and academic contributions that shape this area of research. By mapping key research themes, influential authors, and conceptual developments, this study aims to offer insights into the evolution and current state of sustainability disclosure in extractive industries, identifying gaps and suggesting directions for future research.

Many theories describe the mining industry's motivation to disclose its environmental and social information (Zeng et al., 2010). Legitimacy theory is the most widely accepted study viewpoint on why businesses report on social and environmental issues (Waddock & Boyle, 1995). The foundation of legitimacy theory is the idea of a social contract between the community and

businesses, as well as the notion that businesses will implement tactics, such as disclosure tactics, that demonstrate to the community that they are making an effort to live up to their expectations (Mahmood et al., 2023; Patten, 1991). The extractive sector is crucial in discussions about social and environmental sustainability, and it has recently assumed the role of CSR and environmental responsibility due to a variety of issues (Cowell et al., 1999). The mining industry is one of the most common sources of social and environmental information because of the limited supply of non-renewable resources, the various environmental effects of their utilization and extraction, the economic significance of primary extraction industries in some nations, and the societal impact of mining operations on nearby communities (Tilt & Symes, 1999).

The most common phrase in company reports is "sustainable development," which firms utilize as a framework to highlight their dedication to economic development in the communities where they function as well as their social and environmental responsibilities (Mubeen et al., 2024). Similar to CSR, the sustainable development narrative has gained legitimacy as an organizational articulation of corporate goals (Pellegrino & Lodhia, 2012; Ramos-Meza et al., 2021). The "sustainability model," which incorporates economic, social, and environmental concerns into long-term planning for local communities beyond the closure phase, is the foundation of mining firms' social strategy (Jenkins, 2004). The impact of environmental concerns on company strategy and, consequently, on strategic decision-making is growing (Naseer et al., 2024; Yaseen et al., 2023). Businesses might choose to simply follow the law as it stands or take the initiative and implement more aggressive environmental policies that provide long-term competitive gains (Sánchez, 1998). The mining sector has demonstrated a growing interest in social and environmental concerns since the early 1990s, and it has been looking for methods to incorporate the difficulties of sustainability into its fundamental business operations, according to the literature (Roberts, 1991).

This paper differs from and contributes to the literature in several ways. Much of the previous papers discussed the sustainability disclosure in mining industries and the commitment of the extractive industries towards the communities and environment(Bini et al., 2018; de Villiers et al., 2014). These earlier results support the idea that mining corporations respond to legitimacy issues by disclosing more information, which is taken from legitimacy theory (Lodhia & Hess, 2014). But in this paper, we are doing a bibliometrics analysis of many studies related to

sustainability disclosure in the mining industry. This summary will provide a great advantage worldwide and globally. It will be effective in describing the facts regarding the corporate social responsibilities of mining industries such as copper, gold, uranium, zinc, etc., and their extraction and all issues about their sustainability disclosure.

This study utilizes bibliometric analysis through 'biblioshiny,' the web-based interface of the 'bibliometrics 3.0' R package, to systematically review CSR disclosure in mining. The primary objective is to identify core publications, authors, countries, and institutions using tools like Bradford's law and citation indices (h, g, and m). Additionally, the study explores research themes through mapping techniques of conceptual structures and keyword analysis. Findings are then interpreted to outline future research directions in CSR disclosure within extractive industries.

There are several concerns raised by the state of the world today that require answers. The following questions are taken into consideration for this study in order to offer information on the actual activities of the social science industries as well as to assist in identifying the dynamics of CSR disclosure in the literature on mining companies. This study addresses the following questions.

1. Which sustainability disclosure factors have the most influence in the extractive industries?

2. Explore the literature on sustainability disclosure of mining industries and what are the trends and key themes.

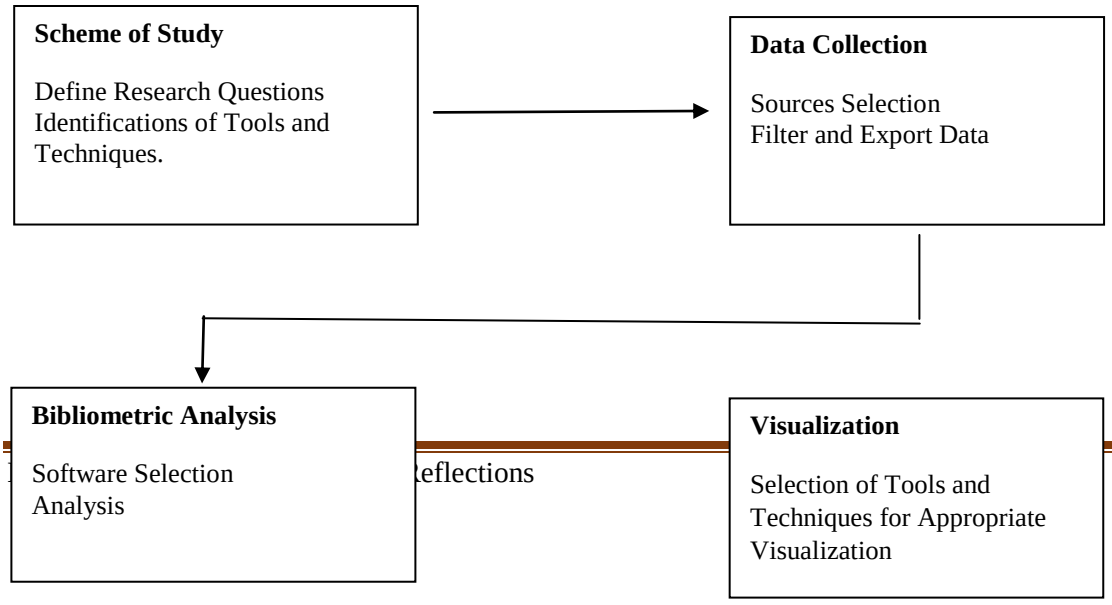
3. What thorough lessons can we learn from the literature of the past, and what agendas can we establish for the future to prepare for it?

This study contributes by providing a descriptive analysis to identify key sources, authors, countries, publications, and affiliations within CSR disclosure in extractive industries. Using metrics such as source impact, total citations (TC), and yearly net publications (NP), we highlight core sources through Bradford's Law, categorizing them into productive, moderate, and low-output zones. We then identify key themes that bridge research streams and suggest future directions using co-occurrence maps, thematic maps, and thematic evolution. Additionally, 'keywords plus' from databases enhance trend identification beyond author keywords, offering

clearer insight into article content. We employ 'biblioshiny' in the R package to conduct this structured bibliometric analysis and uncover the main themes and streams in the literature.

2. MATERIAL AND METHOD

There are two components to the bibliometric data composition. In the first, we choose a few of the articles' sources. We have chosen a few databases for this purpose, including Google Scholar, Emerald, Web of Science, and Scopus. We have developed a search query for comprehensive data collecting in the second section. In order to align the query with our primary goal and achieve the best possible outcomes, we have worked on it. The final search query is 'TITLE-ABS-KEY ("corporate social responsibility" OR CSR OR sustainability OR carbon OR "Carbon emission*" OR "climate change" OR ghg OR "greenhouse gas*" OR environment*) AND TITLE (extract* OR "minin*" OR oil* OR gas*) AND TITLE-ABS-KEY (disclosure*)) AND (LIMIT-TO (LANGUAGE , "English"). Nearly every article is relevant to a search query. We were able to locate 263 social science publications using the last search query. These articles are compiled from the fields of finance, econometrics, economics, business management, and accounting. The conceptual framework generates themes based on keywords, and we restrict our search query to journal papers and English-language publications for appropriate analysis. We may compare keywords, publication sources, and affiliations using a variety of methods provided by bibliometric analysis. Additionally, we personally reviewed the papers and eliminated about twenty that did not align with the study's goal; as a result, our final sample consists of 243 articles. This article follows Zupic and T. Cater's recommended bibliometric workflow, which consists of five parts. The five stages needed to finish the bibliometric study of CSR disclosure in extractive sectors are shown in Figure 1.



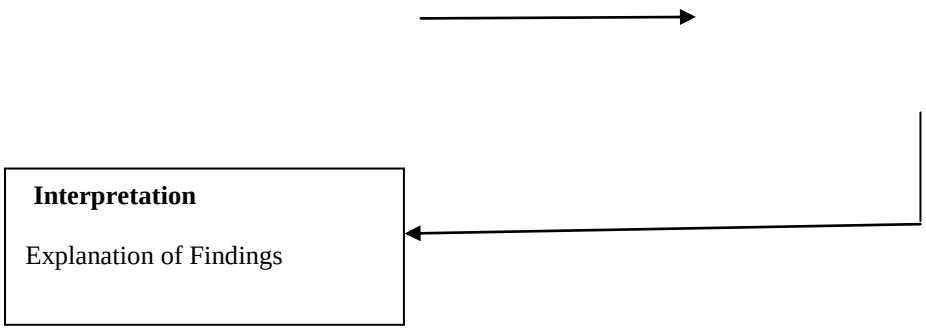


Figure 1. The Procedure of Bibliometric Analysis.

3. Findings

It is the use of several instruments, such as mathematical and statistical techniques, in media and book communication. The bibliometric analysis tool "biblioshiny" assists in locating numerous results in the form of tables and graphs, which are uncommon in other tools. Table 1 gives full details about the descriptive features of CSR disclosure in mining industries, which is important before moving toward the analysis. Every journal uses 185 authors' keywords in addition to 506 keywords. We chose the years 1977–2021 for the extractive industry literature. These texts were written by 153 writers in total, but only 15 of them had a single author. The collaboration index indicates that there is also a high level of cooperation in the CSR publications of the extractive sectors. With an average document-per-author ratio of 0.438, nearly three writers have contributed to a single document.

TABLE1. *Descriptive characteristics of Sustainability disclosure in extractive industries*

Description	**Results**
MAIN INFORMATION ABOUT DATA	
Timespan	1977:2021
Sources (Journals, Books, etc)	52
Documents	67
Average years from publication	7.27
Average citations per document	28.87

Average citations per year per doc	2.992
References	4086
DOCUMENT TYPES	
Article	55
Book	1
book chapter	1
conference paper	4
Review	6
DOCUMENT CONTENTS	
Keywords Plus (ID)	506
Author's Keywords (DE)	185
AUTHORS	
Authors	153
Author Appearances	166
Authors of single-authored documents	15
Authors of multi-authored documents	138
AUTHORS COLLABORATION	
Single-authored documents	15
Documents per Author	0.438
Authors per Document	2.28
Co-Authors per Documents	2.48
Collaboration Index	2.65

Figure 2 shows the annual production for sustainability disclosure in mining industries. In the graph, there is little production at the start, but later in the production increases at a higher rate. We may conclude that there is a growing trend in the publications and citations of mining industry CSR initiatives. Additionally, the number of CSR articles cited annually increased significantly between 2013 and 2015. It is also essential to keep an eye on other subjects, locations, and associations of the extractive sector publications in addition to the yearly production.

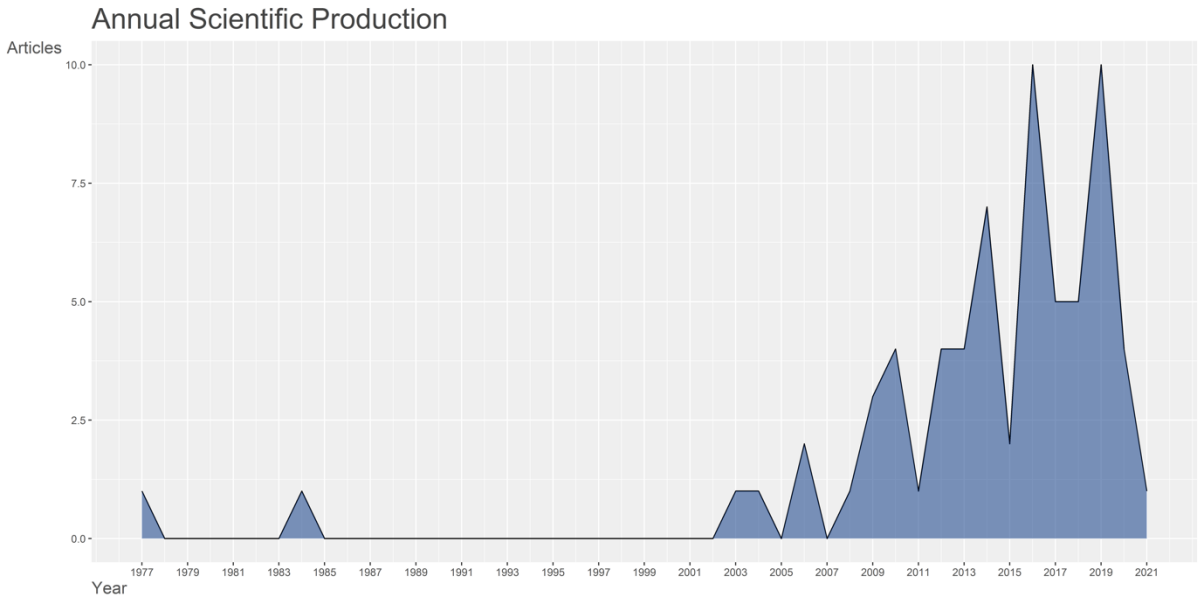


Figure2. **Annual scientific production**.

Figure 3 provides a three-fold analysis of sustainability disclosure publications in extractive industries. On the left, key research topics are listed, representing keywords relevant to the study, such as *environmental management*, the *mining industry*, *sustainability reporting*, and *environmental impact*. The right side displays the names of top-affiliated universities, while the middle section shows countries contributing to this research field. Figure 3 indicates that countries like South Africa, China, the USA, and Australia are significantly engaged in sustainability-related research within extractive industries, with universities in these countries actively publishing on these topics. Prominent keywords in the analysis—*environmental protection*, *sustainability*, *mining*, and *corporate strategy*—highlight the research focus areas relevant to sustainability in high-impact industries. These elements collectively underscore the research contributions and key thematic areas pertinent to the study's objectives.

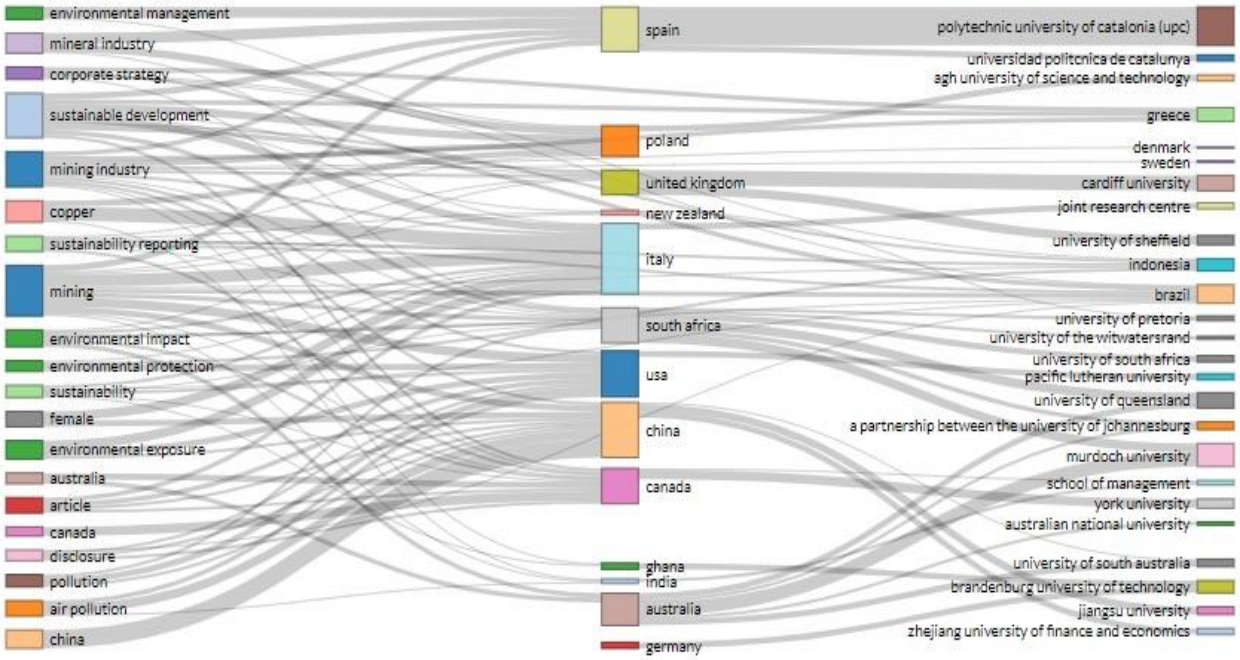


Figure 4. Three-fold analysis of sustainability disclosure in extractive industries

3.1. INFLUENTIAL ASPECTS OF SUSTAINABILITY DISCLOSURE IN MINING INDUSTRIES

1. CORE JOURNALS

We use Bradford's law and source impact to identify the main journals that are active in social science publishing. The papers are ranked in Table 2 according to publication starting (PY-start), h, m, g-index, total citation (TC), and net production (NP). Journal of Cleaner Production stands out with the highest h-index (7), g-index (9), m-index (0.4375), and total citations (859), showing its strong influence and sustained impact. It has also published the most articles (9) since 2006. Other journals like Resources Policy and Sustainability (Switzerland) are also notable, though with fewer publications and lower citation impact. This table highlights key sources in this research field, identifying influential journals.

TABLE 2. *Top ten journals according to source impact.*

Source	h_index	g_index	m_index	TC	NP	PY_start
JOURNAL OF CLEANER PRODUCTION	7	9	0.4375	859	9	2006
RESOURCES POLICY	3	3	0.3	131	3	2012
SUSTAINABILITY (SWITZERLAND)	3	3	0.5	43	3	2016
CORPORATE OWNERSHIP AND CONTROL	1	2	0.1111	28	3	2013
CORPORATE SOCIAL RESPONSIBILITY AND ENVIRONMENT	1	2	0.0556	206	2	2004
ABACUS	1	1	0.3333	7	2	2019
ACCOUNTING FORUM	1	1	0.0909	38	1	2011
ACCOUNTING, AUDITING AND ACCOUNTABILITY JOURNAL	1	1	0.3333	3	1	2019
ACCOUNTING, FINANCE, SUSTAINABILITY, GOVERNANCE	1	1	0.25	3	1	2018
ADVANCES IN ENVIRONMENTAL ACCOUNTING	1	1	0.0625	22	1	2006

Bradford's law, which separates the journal into three zones, is shown in Table 3. Zone 1 represents the primary sources for publishing articles about environmental disclosure. This area, known as the "nuclear zone," stands for journals with significant publications. The Bradford Law rating of journals is also covered in Table 3. We found that 27 of the 262 journals fall within zone 1, with the rest journals being found in zones 2 and 3. An important venue for publishing environmental disclosure in the social science sector is the Journal of Cleaner Production. When the first environmental protection law was enacted in May 2008, mining firms were required to publish environmental information (Zeng et al., 2010). Additionally, according to a Resource Policy Journal article (Hilson & Murck, 2000), a mine can significantly assist in sustainable development at the mine level by improving performance in the socioeconomic and

environmental domains, implementing cleaner technologies and sound environmental management tools, extending social responsibility to stakeholder groups, forming sustainability partnerships, and improving training. There has been significant growth in the publications of the Journal of Cleaner Production since 2012. It shows the primary source for the literature on sustainability disclosure in extractive industries. The mining sector has demonstrated a growing interest in social and environmental concerns since the early 1990s, and it has been looking for methods to incorporate the difficulties of sustainability into its fundamental business operations, according to the literature (Ford, 2004).

TABLE 3. *Journal ranking according to Bradford law.*

Source	Rank	Freq	Zone
JOURNAL OF CLEANER PRODUCTION	1	9	Zone 1
RESOURCES POLICY	2	12	Zone 1
SUSTAINABILITY (SWITZERLAND)	3	15	Zone 1
CORPORATE OWNERSHIP AND CONTROL	4	17	Zone 1
CORPORATE SOCIAL RESPONSIBILITY AND ENVIRONMENTAL	5	19	Zone 1
ABACUS	6	20	Zone 1
ACCOUNTING FORUM	7	21	Zone 1
ACCOUNTING, AUDITING AND ACCOUNTABILITY JOURNAL	8	22	Zone 1
ACCOUNTING, FINANCE, SUSTAINABILITY, GOVERNANCE	9	23	Zone 2
ADVANCED SCIENCE LETTERS	10	24	Zone 2

3.2. Core Journal Articles

The top papers on sustainability disclosure in the extractive industries are highlighted in this area. Table 4 contains a list of the top 10 articles that have been cited worldwide. At the top of the list is JENKINS H's 2006 research, "Corporate Social Responsibility in the Mining Industry:

Exploring Trends in Social and Environmental Disclosure," which examined how mining companies should disclose CSR. The second-most internationally referenced article is JENKINS H.'s 2004 paper, "CORPORATE SOCIAL RESPONSIBILITY AND THE MINING INDUSTRY: CONFLICTS AND CONSTRUCTS," which may be applied to future sustainable disclosure in extractive sectors in the globalized world. They looked into how CSR affected the extractive sectors' standing. In "Disclosure as Governance: The Extractive Industries Transparency Initiative and Resource Management in the Developing World," HAUFLER V discusses how transparency initiatives have proliferated across a variety of topics and how the concept has permeated various institutions. As disparate agendas—anti-corruption and conflict prevention—merged in a normative setting that supported an emphasis on market solutions to social issues, transparency emerged as a focal point for action in the resource sector. The relationship between CSR initiatives and the adoption of environmentally sustainable mining industry practices was examined in VINTR C, 2014, which focused on "Environmental sustainability in the mining sector: evidence from Catalan companies."

TABLE 4. *Most globally cited article.*

Paper	**Total Citations**	**TC per Year**
Corporate social responsibility in the mining industry: Exploring trends in social and environmental disclosure	492	30.75
CORPORATE SOCIAL RESPONSIBILITY AND THE MINING INDUSTRY: CONFLICTS AND CONSTRUCTS	205	11.3889
Disclosure as Governance: The Extractive Industries Transparency Initiative and Resource Management in the Developing World	166	13.8333
Sustainability reporting among mining corporations: a constructive critique of the GRI approach	104	13
Climate change accounting and the Australian mining industry: Exploring the links between corporate disclosure and the generation of legitimacy	95	9.5
Assessing the Evolution of Sustainability Reporting in the Mining Sector	77	5.9231

ENVIRONMENTAL AND SOCIAL DISCLOSURE AND DATA RICHNESS IN THE MINING INDUSTRY	76	4
Social impact assessment in the mining sector: Review and comparison of indicators frameworks	74	18.5
The institutionalization of mining company sustainability disclosures	59	7.375
Environmental sustainability in the mining sector: Evidence from Catalan companies	54	6.75

3.3 CORE WORDS

The most common terms used in extractive industries' environmental disclosure are listed in Table 5. The table is separated into four sections: Authors, Keywords, and more. Title, Abstract, and Keywords. Mining is the most prevalent term around. Mining, business, society, and sustainability are all connected to extractive industries. Disclosure, social, CSR, and reporting have been shown in the keywords as well. There are minimum author keywords in this environmental disclosure. When CSR disclosure is used as a keyword, Keyword Plus covers the wide themes. The link between CSR operations and society is also shown by terms pertaining to humans, men, women, and adults.

TABLE 5. *Most frequent words*

Keywords Plus		**Author Keyword**	
Words	**Occurrences**	**Words**	**Occurrences**
mining	196	mining industry	8
companies	159	mining	7
environmental	145	content analysis	5
disclosure	111	corporate social responsibility	5
social	88	environmental disclosure	5
Study	69	sustainability	5

CSR	65	sustainable development	5
reporting	60	China	4
corporate	58	CSR	4
sustainability	58	sustainability reporting	4
Abstract		Title	

Words	**Occurrences**	**Words**	**Occurrences**
mining	52	mining	19
social	23	sustainable development	13
companies	22	mining industry	11
environmental	21	air pollution	7
disclosure	18	China	6
corporate	17	environmental exposure	6
industry	14	environmental impact	6
responsibility	12	sustainability	6
reporting	11	sustainability reporting	6
sustainability	11	article	5

Figure 5 represents the source growth of journal publications over time, utilizing a smoothing technique to display trends in publication frequency. Each line represents a journal's annual publication trend, with smoother lines indicating locally weighted averages. The graph shows that *the Journal of Cleaner Production* has seen a sharp increase in publications starting around 2005, peaking in recent years, suggesting its prominence in research related to sustainability. *Sustainability (Switzerland)* began increasing in publication numbers around 2011 and has maintained a steady rise, indicating growing interest in sustainability topics. *Resources Policy* experienced growth beginning in the early 2000s, with a moderate but steady increase, reflecting its relevance in resource-related research. *Corporate Social Responsibility and Environmental Management* show an increase in publications starting around 2008, aligning with an increased focus on CSR topics in social science. *Corporate Ownership and Control* saw some initial growth but has remained relatively steady, with minor fluctuations, indicating its niche but stable

role in research. The graph overall suggests that interest in these topics, particularly sustainability and CSR, has grown significantly in recent years.

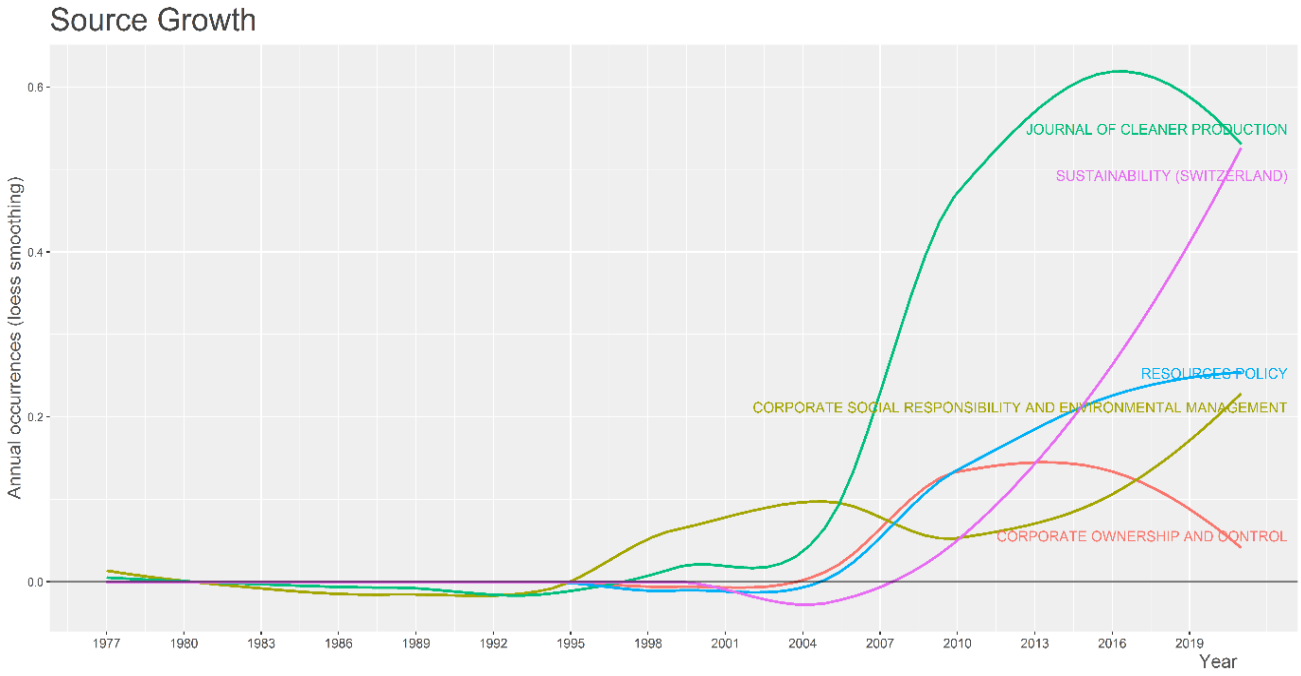


Figure 5. Source Growth

There are many topics related to sustainability disclosure in extractive industries. Many researchers did not use the author's keywords. Mining word is frequently used both in the Title and in the Abstract. The word cloud created using the term addition is seen in Figure 6. Words that appear frequently in literature tend to be larger. The most prevalent topic in the study's literature is mining and the mining sector. Many researchers have done their research on this topic to evaluate the impacts of CSR activities on the economy. There are many studies on the topic of environmental disclosure in extractive industries. Some studies link the mining industry to China, so China is used as a keyword. These keywords are all related to one another and cover a wide range of mining-related activities and their effects on the economy.

FIGURE 6. Word Clouds.

Apart from the word cloud, figure 7 illustrates the evolution of words in literature across time. As the chart illustrates, following 2010, the body of knowledge started to build up in order to address the issues that had previously arisen. Figure 7 examines the evolution of term usage over time using the loess smoothing approach. After 2014, the environmental performance keyword was used less frequently, while issues pertaining to environmental performance increased significantly after 2017. The term "mining" dominated the remaining keywords from 2006 to 2021, although after 2007, the mining keyword somewhat decreased, and the themes linked to sustainability disclosure increased. Keywords including mining, China, sustainability disclosure, and legitimacy theory have all shown an increase.

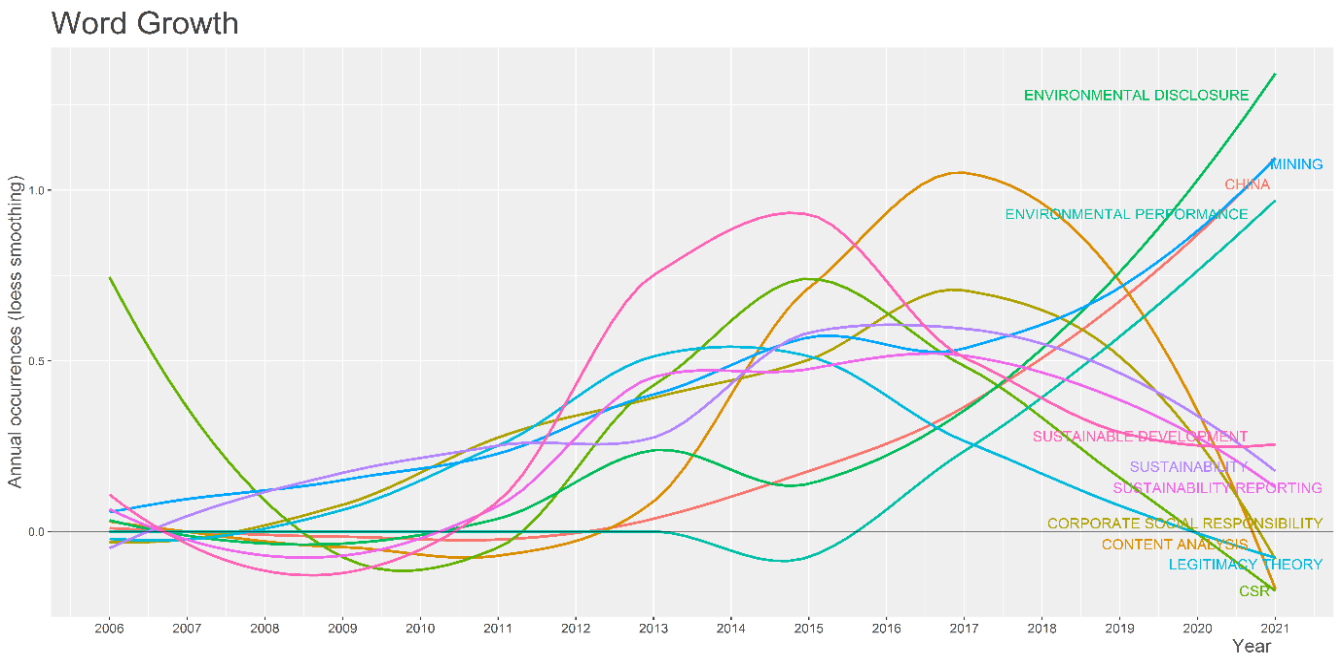


FIGURE 7. Word Growth Overtime.

3.4. Main Authors, Affiliation, Institutions and Countries

The main writers, associations, organizations, and nations of the mining industries are included in this part of the extractive industries. Table 6 lists the 10 writers who have made the most substantial sustainability disclosures in the mining sector. The h-index is used to determine ranking, with VINTR C at the top of the list of writers having the most influence. Dong S is at the 2nd rank in the author's list, while Freijo M is on the 3rd rank, Jenkins H on the 4th rank in the author list, Maroun W is on the 5TH rank, Sanmiquel L is on the 6th rank, Yakovleva N is on the 7th rank, Agyemang AO is on the 8th rank in the author list, Ayamba EC is on the 9th rank in the author, Nasih M is on the 10th rank in the list of top ten authors. In order to measure the progress made towards greater CSR and sustainability goals, Jenkins and Yakovleva N (ranked seventh) published an article on CSR in the mining industry and conflicts and constraints. The study's findings indicated that all mining companies' social and environmental disclosures needed to be more uniform.

TABLE 6. *Top 10 authors in sustainability disclosure in mining industries*

Author	h_index	g_index	m_index	TC	NP	PY_start
VINTRC	3	3	0.25	90	3	2010
DONG S.	2	2	0.167	48	2	2010
FREJOM	2	2	0.2	78	2	2012
JENKINS H	2	2	0.111	697	2	2004
MAROUN W	2	2	0.222	37	2	2013
SANMIQUEL L	2	2	0.2	78	2	2012
YAKOVLEVA N	2	2	0.125	509	2	2006
AGYEMANG AO	1	1	0.5	2	2	2020
AYAMBA EC	1	1	0.5	2	2	2020
NASIHM	1	2	0.333	29	2	2019

Two sets of data are displayed in Table 7; the nations and areas on the left are those that have had numerous sustainable advances over time. There are nations with a lot of citations on the right side. Although Brazil came in second and Australia in third place with a number of publications, the UK has more citations overall than Australia. The UK published 58 articles on sustainable development in mining industries, but they have 147.20 citations.

TABLE 7. *Top countries in terms of publications and citations.*

Country	Total Citations	Average Article Citations
UNITED KINGDOM	736	147.20
BRAZIL	181	90.50
DENMARK	76	76.00
NEW ZEALAND	97	48.50
AUSTRALIA	148	37.00
SPAIN	73	36.50

Country	Total Citations	Average Article Citations
ITALY	94	31.33
RUSSIA	27	27.00
GHANA	18	18.00
CANADA	72	14.40

Table 8 lists the associations that are most pertinent. First up is the POLYTECHNIC UNIVERSITY OF CATALONIA (UPC). A solid foundation for studying sustainable development in the mining industry has been established by the university. The second most pertinent affiliation on the list is CARDIFF UNIVERSITY. JIANGSU UNIVERSITY comes on the third number by its affiliations. At the same time, MURDOCH UNIVERSITY is the 4th number in the affiliation list. The UNIVERSITY OF SOUTH AFRICA is on the fifth list of article affiliations. The University of South Australia is 6th in the list of affiliations and the best university, and it has done much research in the sustainable development of extractive industries. YORK UNIVERSITY is 7th on the affiliation list. The BRANDENBURG UNIVERSITY OF TECHNOLOGY is the 8th number on the list. In the 9th number, the JOINT RESEARCH CENTRE is placed. The PACIFIC LUTHERAN UNIVERSITY is on the 10th list of affiliations.

TABLE 8. *Most relevant affiliations.*

Affiliations	Articles
POLYTECHNIC UNIVERSITY OF CATALONIA (UPC)	7
CARDIFF UNIVERSITY	4
JIANGSU UNIVERSITY	3
MURDOCH UNIVERSITY	3
UNIVERSITY OF SOUTH AFRICA	3
UNIVERSITY OF SOUTH AUSTRALIA	3

YORK UNIVERSITY	3
BRANDENBURG UNIVERSITY OF TECHNOLOGY	2
JOINT RESEARCH CENTRE	2
PACIFIC LUTHERAN UNIVERSITY	2

Figure 8 describes the main countries' affiliations with the topics mentioned above in the study. South Africa and Canada are the top affiliated countries mentioned in Figure 8. This figure represents the data regarding the top 10 countries affiliated with the research of sustainable development of the mining industry.

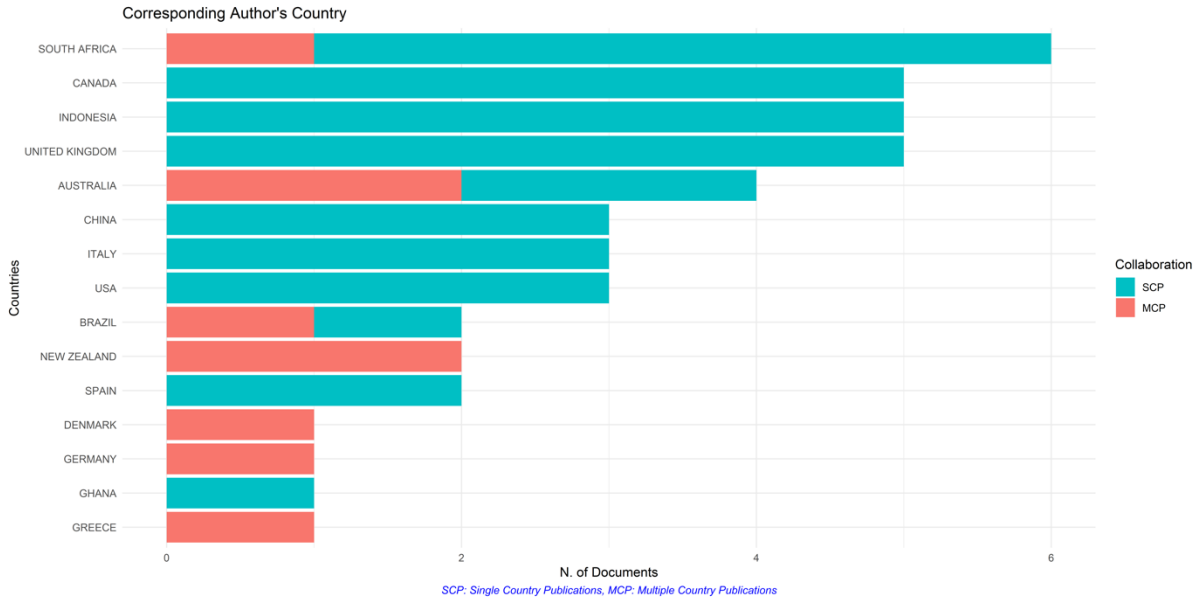


FIGURE 8. Most relevant Affiliations of countries.

This problem has been addressed in Table 9, but regrettably, not many international partnerships have been noted. In two publications, South Africa worked with New Zealand, and in three

papers, it worked with Australia. The remaining nations listed in Table 9 worked together on just one publication.

TABLE 9. *Collaboration network*

From	To	Frequency
SOUTH AFRICA	AUSTRALIA	3
SOUTH AFRICA	NEW ZEALAND	2
AUSTRALIA	CHINA	1
AUSTRALIA	KENYA	1
AUSTRALIA	PORTUGAL	1
AUSTRALIA	SWEDEN	1
CANADA	BRAZIL	1
GHANA	GERMANY	1
SOUTH AFRICA	KENYA	1
SOUTH AFRICA	PORTUGAL	1

3.6. Conceptual Framework

This part uses word relationships (Keyword Plus) to help us grasp a variety of subjects. In order to assess several aspects of sustainable development in the context of extractive industries throughout time, the research first suggests a co-occurrence network. Then, in order to examine the work's centrality and density, we will place these word networks on a two-dimensional matrix known as a "Thematic Map."

3.7. Co-Occurrence Network

The co-occurrence network of keyword plus is displayed in Figure 9. The graphic was taken from the R-package's "biblioshiny" (bibliometric). Four streams of environmental disclosure may be distinguished in the extractive industry sector according to the co-occurrence network of terms. The blue and green clusters are related in terms of themes, whereas the red cluster is the core cluster with the highest centrality. The most centrality is seen in environmental disclosure.

The environmental disclosure is separated into several study streams by each group. The green cluster represents the research streams of environmental disclosure in the mining sector in China. There is a close relationship between mining, air pollution, sustainability reports, environmental performance, social disclosure, corporate governance, and mining companies. The blue cluster represents the research stream of the mining industry and its economic impacts. In this research stream, studies are related to the mining industry, sustainable development, legitimacy theory, and corporate social responsibility. The red cluster represents the research stream of content analysis, which is related to the legitimacy theory, sustainability, and CSR activities in Canada.

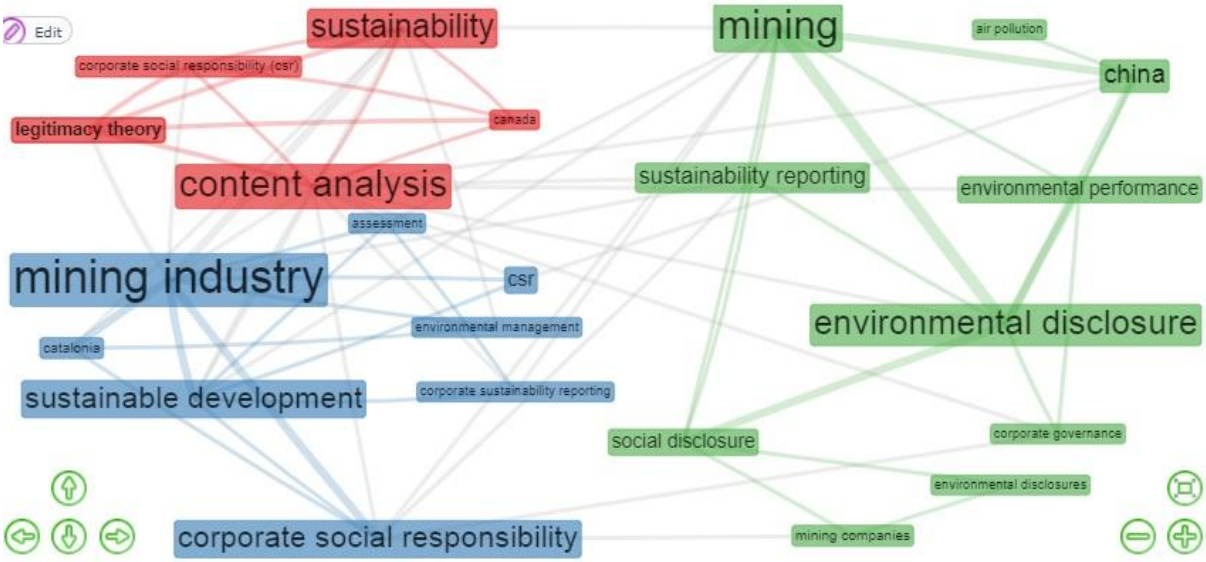


FIGURE 9. Co-occurrence network.

3.8. Thematic Map

This thematic map organizes research themes related to environmental disclosure and sustainability in the extractive industries by their development degree (density, shown on the y-axis) and relevance degree (centrality, shown on the x-axis). The map in Figure 19 separates the themes into four quadrants: fundamental themes, developing or decreasing themes, motor themes, and specialty themes. As motor topics, legitimacy theory and sustainability reporting are located in the upper-right quadrant. These topics are very significant and well-developed within

the discipline, as evidenced by their high centrality and density. This suggests they are critical themes driving research on environmental disclosure in extractive industries. The upper-left quadrant, representing niche themes, includes air pollution, environmental, and environmental management. These themes are well-developed but less central to the main research field. This indicates that, while specialized, they may have limited influence on the broader discourse on sustainability reporting. The lower-right quadrant, which consists of basic themes, includes the mining industry, mining, and mining companies. These themes have high centrality but lower density, showing they are foundational to the field and highly relevant but may benefit from further development. These themes likely form the basis of much of the literature on sustainability disclosure within mining. The lower-left quadrant, labeled emerging or declining themes, contains annual reports and firm size. These themes have low centrality and density, suggesting that their significance may be either increasing or decreasing within the field. Firm size as an emerging theme might reflect a growing interest in how the scale of a company influences its sustainability practices and disclosure levels. Overall, this thematic map provides an insightful snapshot of the field's current state, showing which themes are central, well-developed, emerging, or potentially declining in the context of sustainability disclosure within the extractive industries.

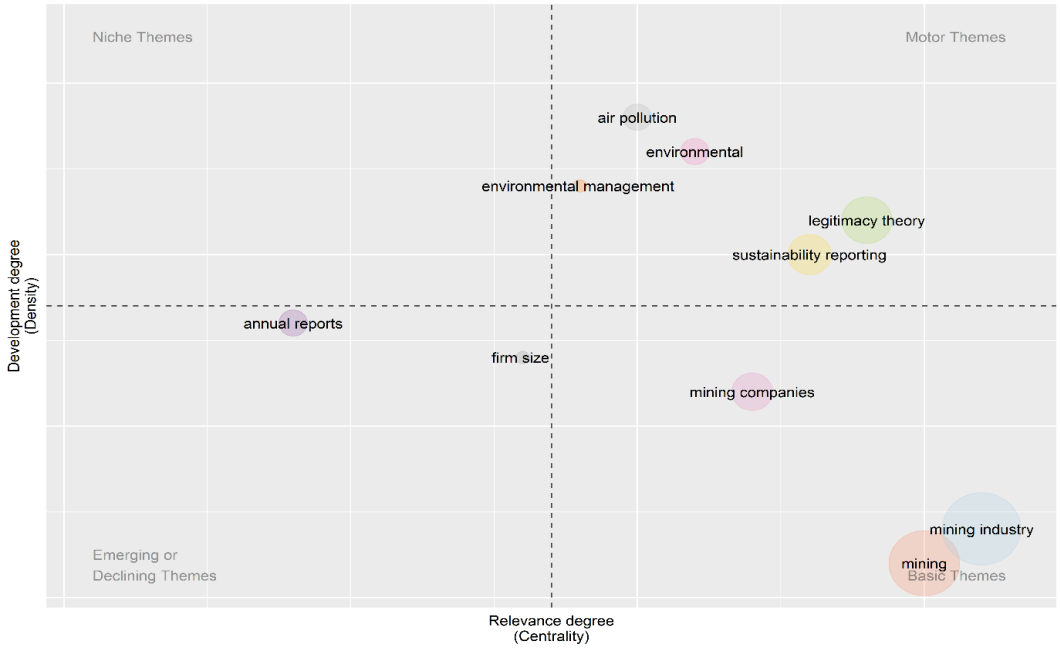


FIGURE 10. Thematic Map

3.9. Thematic Evolution

In Figure 11, the thematic evolution diagram shows the progression of sustainability disclosure literature in the extractive industries over four time segments: 1977-2012, 2013-2016, 2017-2018, and 2019-2021. Created using "biblioshiny," the diagram illustrates the development of research themes and how they have evolved. In the first segment (1977-2012), foundational themes emerged, including *environmental*, *disclosure*, *gas*, *firms*, *approach*, and *reporting*. These topics formed the basis for sustainability-related discussions in the extractive industries, focusing on general environmental concerns, corporate approaches, and disclosure practices. During the second segment (2013-2016), more specific topics like *corporate*, *mining*, *practices*, and *sector* began to take shape, indicating a shift towards targeted research on corporate responsibility, sector-specific practices, and the economic impacts of mining. These themes built on the foundational topics from the previous period and reflected a growing recognition of corporate accountability in the industry. The third segment (2017-2018) saw further refinement with *environmental*, *development*, *mining*, and *sustainability themes*. These themes emphasized sustainable development and the mining sector's broader impacts, along with more focused studies on environmental management and CSR activities. This period showed a maturation of earlier themes, aligning with global discussions on sustainable development. In the final segment (2019-2021), the themes consolidated around *data*, *mining*, and *reporting*. This indicates an increased emphasis on data-driven approaches, sophisticated reporting methods, and continued focus on mining, suggesting that research in sustainability disclosure has reached a more advanced stage. Reporting and data analysis have become integral in ensuring transparency and accountability within the industry. Overall, the diagram illustrates a clear evolution from broad environmental topics to more sophisticated, data-centric approaches in sustainability reporting, showing how research in the field has matured over time. This thematic progression highlights the increasing importance of transparency, accountability, and corporate responsibility in the extractive industries.

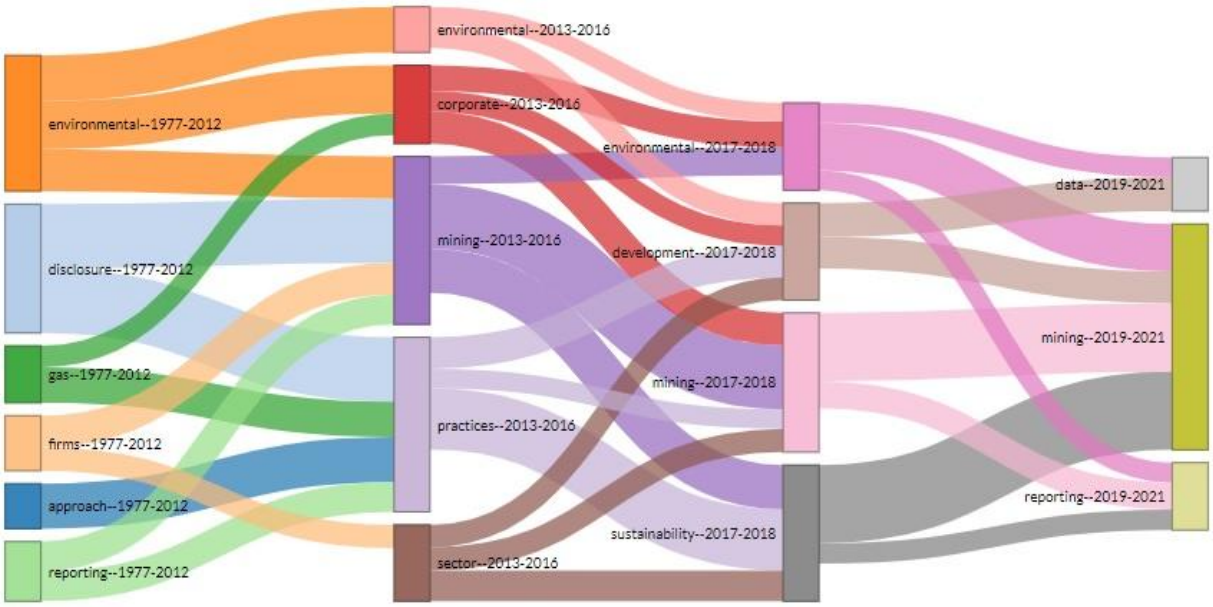


FIGURE 11. Thematic Evolution

4. CONCLUSION

In conclusion, this study offers a comprehensive bibliometric analysis of sustainability disclosure in extractive industries, addressing key themes, research clusters, and thematic developments. The conceptual framework highlights the interconnectedness of various themes, with a focus on environmental and sustainability topics. By leveraging the co-occurrence network of keywords, we identified four main research clusters, each reflecting distinct thematic areas within environmental disclosure. The red cluster, with high centrality, underscores the significance of environmental disclosure and connects closely with corporate governance and CSR themes. This central cluster, alongside the blue and green clusters, illustrates the sector's varied focus areas, such as the economic impacts of the mining industry, environmental performance in China, and content analysis within Canadian contexts. The thematic map further clarifies these themes, categorizing them by centrality and density to indicate their importance and developmental stage. Themes in the lower right quadrant, identified as basic or transversal, represent foundational research areas, particularly in sustainability disclosure. In contrast, the upper right quadrant houses “motor themes,” which are well-developed and critical, such as the mining industry's role in sustainability practices. The upper left quadrant shows isolated but mature themes, indicating areas where significant research exists but with limited cross-disciplinary connections,

suggesting potential for expanded studies. The thematic evolution analysis provides insights into the historical progression of sustainability research in extractive industries. Starting from foundational studies in environmental disclosure from 1977 to 2012, the field has witnessed a thematic shift over successive periods. Between 2013 and 2016, the focus expanded to cover broader topics in mining and CSR, while the 2017-2018 period saw an emphasis on environment-related activities and disclosure practices. The latest segment (2019-2021) reveals an integration of themes around the comprehensive bibliometric mapping of mining literature, reflecting a growing recognition of environmental accountability in the sector. This study's findings underscore the evolving importance of sustainability and environmental themes in extractive industries. By mapping these themes, this analysis not only highlights the current landscape of sustainability disclosure but also identifies emerging areas with the potential to become future focal points. Such insights provide a valuable roadmap for researchers, enabling them to explore underdeveloped areas or expand on established themes, ultimately contributing to a deeper understanding of sustainability practices in high-impact industries.

4.1. Future Directions

Based on the analysis of the current trends and key themes, several future research directions can be outlined. First, conduct cross-country comparative studies on sustainability disclosure practices in extractive industries, focusing on how regulatory environments and cultural contexts influence disclosure quality and themes. Second, investigate how firm size influences the scope and content of sustainability disclosure in mining companies, particularly in emerging economies, where regulatory pressures may differ. Third, explore how corporate governance structures, such as board diversity and independence, affect sustainability disclosure in extractive industries, especially regarding environmental and social performance. Fourth, analyze the relationship between CSR activities and financial performance in mining companies, assessing whether comprehensive sustainability disclosure enhances investor confidence and profitability. Fifth, perform longitudinal studies to track the evolution of key themes in sustainability disclosure, extending beyond the 2021 timeframe to capture ongoing developments and emerging trends in environmental accountability. Sixth, examine the specific environmental impacts of mining activities in developing countries, focusing on how these impacts are reported and managed through sustainability disclosures. Seventh, investigate emerging themes in

sustainability reporting, such as climate resilience and biodiversity preservation, assessing their potential to become foundational topics in future mining industry research. Eighth, study the application of legitimacy theory in shaping sustainability disclosures, particularly in regions where extractive industries face significant social opposition or environmental scrutiny. Ninth, research how digitalization, such as blockchain and data analytics, could enhance transparency and accuracy in ecological reporting for extractive industries, improving stakeholder trust. Tenth, evaluate the effect of international sustainability standards (such as GRI and SASB) on the quality and consistency of sustainability disclosures in global mining companies, identifying areas where standardization may be lacking.

4.1. Limitations of the Study

This study is limited by the scarce literature on sustainability disclosure in the mining industry, which may restrict the depth of analysis. Broader research across different countries is needed to understand these practices' economic and environmental impacts globally. Another limitation is the reliance on "keywords plus" instead of author keywords due to the limited availability of the latter. This may affect theme specificity, as keywords plus may not fully capture the authors' intended focus. Future studies could combine both types of keywords for a more accurate thematic framework.

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